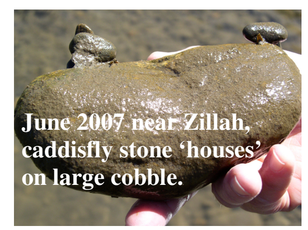
Microhabitat limitations

Could upwelling of water from the hyporheic zone — where surface water and groundwater intermingle below the river bed — provide periphyton in the Zillah reach another source of nutrients? Yes, at some locations. Of the 14 sites where subsurface porewater in the river bed was sampled, all sites had higher soluble reactive phosphorus in porewater than in surface water and ten sites had higher nitrate concentrations in porewater. At seven of the 14 sites, the pressure difference between the surface water and porewater was measured to see if hyporheic water was coming into the river or if the river was losing water into the hyporheic zone. Three sites were upwelling and four sites were downwelling. On a reach scale, recent seepage (flow) measurements conducted by USGS-Tacoma found several miles of the Zillah reach were gaining and the rest were losing (Vacarro, Feb. 28, 2007 presentation, at http://wa.water.usgs.gov/projects/yakimagw/data/YakimaPPT22807.pdf). At both microhabitat and reach-scale levels, nutrients coming from the hyporheic zone may be an important factor in determining patterns in algal growth abundance.

The variability in algal biomass was not explained by water depth, but only a narrow range of depths (0.5-2.5 feet) was evaluated. Velocity was more strongly related to biomass, explaining 67% of the variability in chlorophyll *a* concentrations at one site but only 23% of the variability when considering all sites. Out of 28 measurements, as velocity increased from 0.1 to 1.5 feet per second, biomass increased from a range of 9-72 mg/m^2 to 45-237 mg/m^2. Higher but non-scouring velocities could possibly increase biomass by enhancing nutrient delivery rates to cells within the algal mat, by removing waste produced during metabolism, or by reducing competition by bacteria within the algal mat.

Although grazing by invertebrates and fish was not part of this study, field observations of benthic invertebrate grazers such as *Heptgeniid* Mayflied, *Glossosomid* Caddisflies, and snails indicated that some grazing was occurring, but we do not know how much it affected algal abundance.


June 2007 near Zillah, caddisfly stone 'houses' on large cobble.

Future Management Considerations

Of the 116 miles of the lower Yakima River, the Zillah reach had the lowest nutrient concentrations and thus the least reduction needed to reach nutrient levels which could limit algal growth and improve dissolved oxygen and pH conditions. The data from this study did not suggest a concentration at which limitation might occur. The data collected to determine if nitrogen or phosphorus was closer to limiting concentrations were inconclusive. Widely varying habitat conditions with complex relationships made reach-scale assessments very difficult. The lack of correlation between nutrient concentrations in surface water and algal biomass presents challenges to efforts aimed at controlling algal biomass. Efforts to work voluntarily with landowners who want to improve their fertilizer practices should continue, with the goal of reducing surface water runoff and leaching from crops, pastures, and lawns. The level of effort needed to reduce the amount of nutrients and algal growth in the river, however, will remain unknown until a better understanding is developed.


Filamentous green algae in the Zillah reach, June 2004.

Other factors which potentially limit algal growth include light, temperature, substrate stability, water velocity, and grazing by invertebrates. Some of these factors could be altered by future planned increases in flow in the Zillah reach but modeling their interrelationships under different flow conditions was beyond the scope of this study.

Conclusions

Nutrient enrichment has allowed excessive algal growth throughout the lower Yakima River. Upwelling of nutrient-rich hyporheic water could provide an additional source of nutrients to algae in some locations. Factors limiting algal growth at times and in specific places included water velocity, light availability, and substrate type. Between reaches, algal growth rates increased with increasing nutrient concentrations. In the Zillah reach, which had the lowest nutrient concentrations within the lower Yakima River, one-third of the algal biomass samples exceeded a non-regulatory nuisance threshold of 100 mg/m^2. Algal biomass (AFDM) increased with decreasing nutrients, likely due to uptake of nutrients by the more plentiful algae.

This handout is one of a series of five handouts on different topics relating to nutrient-enrichment processes in the lower Yakima River. For more information, contact the South Yakima Conservation District at (509) 837-7911.

Algae in the Lower Yakima River

South Yakima Conservation District

April 2008

Benton Conservation District

The U.S. Geological Survey, South Yakima Conservation District, and Benton Conservation District worked together to study the lower 116 miles of the Yakima River from 2004 through 2007 to learn more about nutrients, algae, rooted aquatic plants, and dissolved oxygen and pH conditions in the river. One key purpose of the study was to try to understand what conditions were associated with excessive algae growth. Why the concern? Excessive algae in rivers may result in insufficient dissolved oxygen due to plant respiration and high pH levels due to photosynthesis. Reducing the amount of algae could improve dissolved oxygen and pH conditions. But to control growth, it is first necessary to understand what allows excessive growth.

The opinions and conclusions expressed in this flyer are those of the conservation districts, not the U.S. Geological Survey. The final project report from USGS is not yet complete. This information is being provided before the final report because of timing constraints from the grant funding which paid for this work.

Introduction

Benthic algae are an important component of healthy rivers because they filter out nutrients and produce energy, forming the basis of the food web. But when algal growth becomes excessive due to elevated nutrient concentrations, problems can occur, including low dissolved oxygen, high pH, clogged irrigation screens, elevated bacteria, and impaired aesthetics. To begin to understand which factors affecting algal growth are most important in the Yakima River, 116 miles of the lower river and a few miles of the Naches River were surveyed in 2004 to see what kinds of algae were present and their relative abundance.

Types and Relative Abundance

Diatoms were the most common type of algae in the cobble-dominated Zillah reach and Naches River. Luxuriant growth was observed throughout the reach in suitable habitat areas, frequently in summer but as early as March and as late as October. Filamentous green and blue-green algae also were present, particularly in shallow areas. Phytoplankton was the dominant type of algae in the Mabton pool reach but significant blooms were not observed. Small floating mats of blue-green algae, however, were observed on several occasions in the pooled Mabton reach. Large growths of filamentous green algae were frequently observed in the cobble-dominated Kiona reach, including *Cladophora*, a species indicative of nutrient-enriched waters. Luxuriant growth of diatoms on the rock substrate was not observed; however, growths of epiphyton (algae attached to large plants) were observed in shallow or slow-moving areas in the Kiona reach, especially when plant abundance was highest in 2004 and 2005.

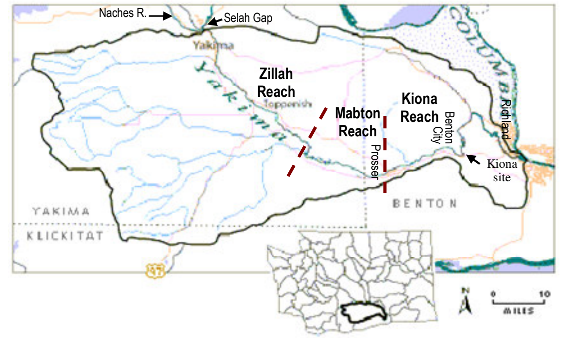

Thick diatom growth on rock, Zillah reach, July 2006.


Strand of *Cladophora*, Sept. 2003, between Whitstran and Benton City.

Key terms

- Benthic algae, also called periphyton. Algae growing on surfaces (rocks, plants, mud, etc.) in streams and rivers. Four types of periphyton observed in the Yakima were:
  - Diatoms. Often is the slime on rocks that make them slippery to walk on.
  - Filamentous green algae. Sometimes looks like a fuzzy green beard.
  - Epiphyton. Algae that grows on large aquatic plants.
  - Blue-green algae, also called cyanobacteria. Able to fix inorganic nitrogen into an organic form of nitrogen.
- Phytoplankton. Single-cellular algae floating in water, often responsible for a greenish-colored tinge to lakes.

Limiting Factors



What factors could account for varying amounts and types of algae in the lower Yakima River? Factors which influence how fast algae grow include nutrients, light and temperature. Factors which influence algal loss rates include substrate stability, water velocity, and grazing by fish or invertebrates. When growth and loss processes are in balance, algae populations are kept in check. The study did not try to quantify all possible relationships between algae and their potentially limiting factors but focused on a few reach-scale and microhabitat conditions — especially focusing on nutrients, since nutrient enrichment is considered one of the leading causes of degradation in U.S. streams.

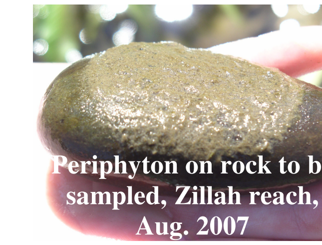
On a reach scale, there were sufficient nutrients, light, and temperature to allow abundant algal growth in each reach during the summer of 2005. Yet there were places within each reach with visibly sparse growth. Why? In some riffles, water velocity appeared to be too high to allow for abundant algal growth. In the Mabton reach, where conditions were more favorable for phytoplankton, the residence time was apparently short enough to prevent large or visible algal blooms. In other places, the reason for minimal algal growth was unknown. For example, in the Zillah reach, algal biomass was sampled only at sites that were suitable for periphyton growth (shallow, non-scouring velocity, ample light, warm water, sufficient nutrients) yet only 18 out of 48 samples exceeded a non-regulatory threshold of 100 mg/m^2 chlorophyll *a* indicating nuisance algal conditions. Processes such as grazing by invertebrates and sloughing events (when algae mats naturally lose their hold on the river bottom) may have restricted growth. Both of these processes were observed in the Zillah reach but not quantified.

Early in the study, it was hoped the Zillah reach would have nutrient-limiting conditions against which to compare the rest of the lower river. When it was apparent that this was not the case, a few samples were obtained in the lower Naches River, with its much lower nutrient concentrations. Surprisingly, algal biomass in the few samples from the Naches River was similar to the Zillah reach (see next page).

Reach	Zillah	Mabton	Kiona
Dissolved inorganic nitrogen **Soluble reactive phosphorus**	0.01-0.62 mg/L DIN 0.009 to 0.043 mg/L SRP	0.76-1.1 mg/L DIN 0.05 to 0.105 mg/L SRP	0.6-1.18 mg/L DIN 0.056 to 0.014 mg/L SRP
Light	Rarely limiting in 2005. Often limiting in spring 2006. Not measured in 2007.	Sometimes limiting in 2005 in deepest parts of the reach. Not measured in 2006 and 2007.	Rarely limiting in 2004 & 2005. Often limiting during spring 2006 & 2007.
Temperature	Mar.-Oct. 2005 median daily maximum temperature 18.5º C.	Mar.-Oct. 2005 median daily maximum temperature 19.4º C.	Mar.-Oct. 2005 median daily maximum temperature 19.7º C.
Substrate stability	Unstable. Braided channel on top of alluvial fill. Cobble moves even below flood stage.	Mud likely deposited annually during irrigation season and moved during high water events.	River channel constrained by bedrock. Cobble unlikely to move except in the most extreme floods.
Average water velocity	1.5 ft/sec	0.8 ft/sec	1.5 ft/sec
Grazing	Not quantified. *Heptageniid* Mayflies and *Glossosmid* Caddisflies present.	Not quantified. Snails and midge larvae present.	Not quantified. *Hydropscychid* and *Brachycentrus* Caddisflies and Corbicula Clams present.
Algal biomass	18 out 48 rock scraping samples exceeded nuisance level of 100 mg/m^2. Most >100 mg/m2 samples were in July 2005 but a few also were in Sept.-Oct. 2006 and Aug. 2007.	Out of 23 water samples, median chlorophyll *a* 12.4 mg/m^3 (7 samples ≤ 10 mg/m^3, 8 samples 11-15 mg/m^3, and 8 samples >15-20.7 mg/m^3).	1 rock scraping sample, 8 mg/m^2 chl *a*. Observations: Luxuriant growth of filamentous green algae in some locations; thick epiphytic growth at times and in some places.
Algal growth rate	Chl *a* 0-1.5 mg/m^2/day	Not measured.	Chl *a* 1-2.2 mg/m^2/day
Dominant Types of Algae	Diatoms	Phytoplankton	Filamentous algae and epiphyton

Zillah reach in 2005, 2006, and 2007


Periphyton, Kiona reach, July 2007


Periphyton on rock to be sampled, Zillah reach, Aug. 2007

Because the Zillah reach had high periphyton abundance yet the lowest nutrient concentrations in the lower river, it was identified early in the study as having the best potential for improving conditions through future nutrient-reducing efforts. So more intensive studies were conducted in 2005, 2006, and 2007 to better understand relationships in the Zillah reach. Key questions included:

(1) Was the concentration of nitrogen or phosphorus low enough to limit algal growth? (Important to learn since clean-up strategies differ for each nutrient.);
(2) Did the amount of algae increase with increasing nutrients?; and
(3) How did select microhabitat factors (upwelling groundwater, depth, or velocity) influence the amount of algae?

Nitrogen or phosphorus limitation?

Algae need 7.2 parts of nitrogen for every part of phosphorus they take up for growth. When the ratio of dissolved inorganic nitrogen to soluble reactive phosphorus (biologically-available forms of nutrients) in the water is over 7, phosphorus would be the first nutrient to become in short supply and thus potentially limit growth. When the ratio is less than 7, nitrogen could limit growth. Out of 83 water samples obtained in 2005-2007, 64 (77%) had a ratio less than 7, which suggests that nitrogen would run out first.

Another method to determine the limiting nutrient is using artificial substrate with high-dose nutrients to see if algal growth rates increase when either nitrogen or phosphorus is super-abundant. One such method is to place periphytometers — which are racks of vials where algae can grow on filters in contact with different nutrient solutions — in the river. In 2006 and 2007, periphytometers were deployed primarily in the Zillah reach, but also in the Naches River and the Kiona reach of the lower Yakima River in 2007 to give a broader range of nutrient conditions. Results? Algal growth rates on filters without nutrients were higher in the Kiona reach than the Zillah reach or Naches River sites. The Zillah reach was neither nitrogen or phosphorus limited when looking at all the treatments at all the sites; however, a weak nitrogen limitation was observed at river mile 89 in late July 2006 and a weak phosphorus limitation was observed at river mile 103 in late August 2007. The Naches River was nitrogen limited at two out of three sites. The Kiona site was neither nitrogen or phosphorus limited.

Nutrient concentrations in surface water versus algal biomass

Within the samples from the Zillah reach, there was no relationship (r^2< 0.1) between chlorophyll *a* concentrations and nitrate+nitrite or soluble reactive phosphorus concentrations. There was a weak, inverse relationship between ash-free dry mass (AFDM) and nutrients (r^2=0.46 for nitrogen and 0.42 for phosphorus) — as nutrient concentrations decreased, AFDM increased. This was possibly a result of uptake by algae: the nutrients measured in the river were the nutrients remaining after algal uptake. Nutrient-rich groundwater (see next page) also may have complicated the relationship between algal biomass and nutrients in surface water.

How did the amount of algae in the Zillah reach compare to algae in the lower Naches River with its lower nutrient concentrations? Chlorophyll *a* and AFDM concentrations were less variable in the Naches River but within the range observed in the Zillah reach, even though nutrient concentrations were quite low in the Naches River — <0.01 to 0.04 mg/L nitrate+nitrite and < 0.003 to 0.009 mg/L soluble reactive phosphorus.